NOVEL APPLICATION OF LabVIEW IN HIGH VOLTAGE ENGINEERING

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF
Bachelor of Technology

in

Electrical Engineering

by

Deepak Kumar Singh (108EE012)

Janmejaya Hota (108EE070)

Satyajeet Nayak (108EE015)

Department of Electrical Engineering

National Institute of Technology, Rourkela

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Under the guidance of

Prof. Subrata Karmakar

Department of Electrical Engineering

National Institute of Technology, Rourkela

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2012

National Institute of Technology

Rourkela

CERTIFCATE

This is to certify that the thesis entitled, "**Novel Application of LabVIEW in High Voltage Engineering**" submitted by Deepak Kumar Singh, Janmejaya Hota and Satyajeet Nayak in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Electrical Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any Degree or Diploma.

Date:

Prof. Subrata Karmakar
Dept. of Electrical Engineering
National Institute of Technology, Rourkela
Rourkela-769008

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Place: National Institute of Technology, Rourkela

Date:

Deepak kumar singh

Satyajeet nayak

Janmejaya hota

ABSTRACT

High voltage equipments are often placed in open air and they are often exposed to lightning strike as well as surge voltage. Most of such high voltage power equipments are placed in the power transmission line. They are sustaining high surge voltage during the lightning phenomena. To protect all such power equipments and quality power supply the study of lightning characteristics is most important for every power engineers.

Lightning impulse voltage and standard impulse voltage (1.2/50 μs) are similar to each other. So, to achieving better protection of high voltage equipment study of impulse voltage waveform is very important. A comparison has been made between standard impulse waveform obtained by simulating Marx impulse generation circuit in LabVIEW Multisim and practical Marx circuit. This impulse waveform can be used to test the capacity of electrical equipment against the lightning and switching surge voltage.

So, generation and simulation of an impulse wave has been carried out by the help of LabVIEW Multisim Software Package. A practical Marx circuit has been made and its comparison has been drawn with standard impulse voltage. Data acquisition of the practical impulse voltage generation circuit has been performed.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

Introduction

1.1 IMPOTANCE OF HIGH VOLTAGE ENGINEERING

Most of the high voltage equipment such as power transformer, surge arrester, circuit breaker, isolator and high tension transmission line towers are placed in transmission substations. As these equipments are very costly and important for maintaining continuity of power supply, there safety should be the major priority for an electrical engineer. These equipments are often affected by lightning strokes and switching surge voltages which can cause insulation failure, incipient faults etc. So in order to protect these equipments a prototype of the same can be used to test against lightning strikes.

Generally, there are very few technical institutions that provide high voltage laboratory facility because it involves high capital cost for installation of new high voltage equipment. However, to test the insulation condition of such high voltage power equipment various types of tests are performed to observed the standard value of insulation parameters in the high voltage laboratory. To know the standard value of different insulation different high voltage tests are conducted in the high voltage laboratory. For an example, a list of experiments conducted in high voltage laboratory, they are Breakdown voltage test of transformer oil, Conduction and breakdown in Gaseous Dielectrics, High AC voltage, Impulse voltage test, Flashover Experiment, Soil Resistivity Test, and Condition Monitoring of Distribution Transformer etc. Among these all tests Impulse voltage test is one of the important test for withstand capability of the high voltage insulation level. In this work, an attempt has been made to perform impulse voltage test using a prototype model on a reduced scale (1.2/50 μs, 5 V DC input). Further, the simulation of the same circuit has been carried out in LabVIEW Multisim to compare with the practical result. Therefore, an alternating method for performing these experiments using LabVIEW Multisim in the institutions where high voltage test facilities are not exists.

1.2 APPLICATION OF LabVIEW IN HIGH VOLTAGE ENGINEERING

Lightning characteristics and standard impulse voltage waveform characteristics are similar to each other. So in order to produce better protection scheme against lightning and surge impulse voltage, study of impulse voltage is very much important in the field of High Voltage Engineering. Artificially lighting impulse voltages are generated in high voltage laboratory and can be used to test against high voltage on the high voltage power equipment. These impulse waves having different characteristics such as front time, tail time, peak impulse voltage and similar impulse voltage waveforms are simulated in LabVIEW Multisim and further it is compared with the actual impulse waveform. LabVIEW Multisim is used for this purpose because it provides various features which are very user friendly and provide accurate real time analysis for end users. Moreover, the data acquisitions from the LabVIEW are performed for better analysis of lighting impulse voltage waveform. Thereafter, the standard impulse voltage waveform can be used to test the strength of electrical equipment against the surge voltage due to line loading and lightning.

1.3 OBJECTIVE

The purpose of this research is to develop a LabVIEW simulation circuit that will generate an impulse voltage wave, and to develop a practical circuit that can produce an impulse voltage. Then to compare the theoretical result with the result produced from impulse generator circuit. After that the final goal is to perform data acquisition through 'LabVIEW Signal-Express' to observe the waveform in computer.

1.4 INTRODUCTION TO LABVIEW AND MULTISIM

LabVIEW (short for Laboratory Virtual Instrumentation Engineering Workbench) is a system design platform and development environment for a visual programming language from National Instruments. LabVIEW is generally used for performing circuit simulation, data acquisition, controlling instruments from PC, and industrial automation on a variety of operating systems including Microsoft Windows, LINUX etc. The version used in this project is LabVIEW 2010.

NI Multisim (formerly Multisim) is an electronic schematic capture and simulation program which is part of a suite of circuit design programs, along with NI Ultiboard. Multisim is widely used in academia and industry for circuit simulation, schematic design and SPICE simulation. It is one of the few circuit design programs to employ the original Berkeley SPICE based software simulation. Multisim was originally developed by a company named Electronics Workbench, which is now a part of National Instruments. Multisim includes integrated import and export features to the Printed Circuit Board layout software in the NI Circuit design suite [6].

The NI Multisim Fundamental Circuits series provides different types of circuit topologies and commonly used circuits which are essential in the understanding of characteristics of the same. Multisim, provide a very powerful starting point to build a variety of circuits involving various components, parameters, and the feature of interactive SPICE based simulation and analyses [7]. By using simulation result, engineers can regulate circuit characteristics and optimize its performance. The result is accurate analysis, improved behavior and performance as well.

1.5 INTRODUCTION TO LABVIEW DATA ACQUISITION AND INSTRUMENT CONTROL

Data acquisition (DAQ) is the process of acquiring an electrical or physical phenomenon such as current, voltage, temperature, pressure or sound with a computer. A DAQ system consists of a DAQ card or sensor, hardware from which data to be acquired and a computer with associated software. A DAQ card comes with various features which can be used for different purposes. For data involving micro second accuracy the sampling rate of the card should be high enough to reconstruct the signal to be appeared in the computer. NI USB-6363 DAQ can be used to acquire data related to impulse voltage which require micro second accuracy. Sampling rate of this card is 2MS/s (mega samples per second). This DAQ can be used in variety of platform like Microsoft windows, MAC, and Linux etc. For acquiring data from high voltage system, first the system parameters should be scaled down to values supported by the DAQ card. So the high voltage system should be connected to instrument transformer to scale down the voltage as well as current.

For remote control of a system (stand alone mode), CompactRIO can be used which provides embedded control as well as data acquisition system. The CompactRIO system's tough hardware configuration includes a reconfigurable field-programmable gate array (FPGA) chassis, I/O modules, and an embedded controller. Additional feature of CompactRIO is, it can be programmed with NI LabVIEW virtual instrument and can be interfaced with a variety of control and monitoring applications. Controlling hardware involves sending a signal to a relay from PC which actuates depending up on the users [7].

1.4 ORGANISATION OF THESIS

This thesis is classified into five chapters. First chapter deals with the introduction part. It focuses on importance of high voltage engineering and use of LabVIEW in high voltage engineering. Second chapter deals with background and literature review of impulse voltage. It mainly gives the idea about characteristics of impulse wave, generation of impulse wave and various circuits that can produce impulse wave. Third chapter deals with experimental setup used in this thesis. It also explains controlling of impulse wave shape and mathematical derivation of various components of impulse wave. Fourth chapter deals with the simulation and results of impulse generation circuit and waveforms observed in CRO of practical Marx generator circuit model. The final chapter is the conclusion and summery part. It also explains the future work that can be implemented in this thesis.

CHAPTER 2

Background and Literature Study

2.1 STANDARD IMPULSE WAVE SHAPE

Transient over voltages caused by lightning and switching surges causes steep build-up of voltage on transmission line and other electrical equipment. Experimental investigation showed that these waves have a rising time of 0.5μs to 10 μs and decay time to 50% of the peak value of the order of 30μs to 200μs. The wave shapes are arbitrary but mostly unidirectional.

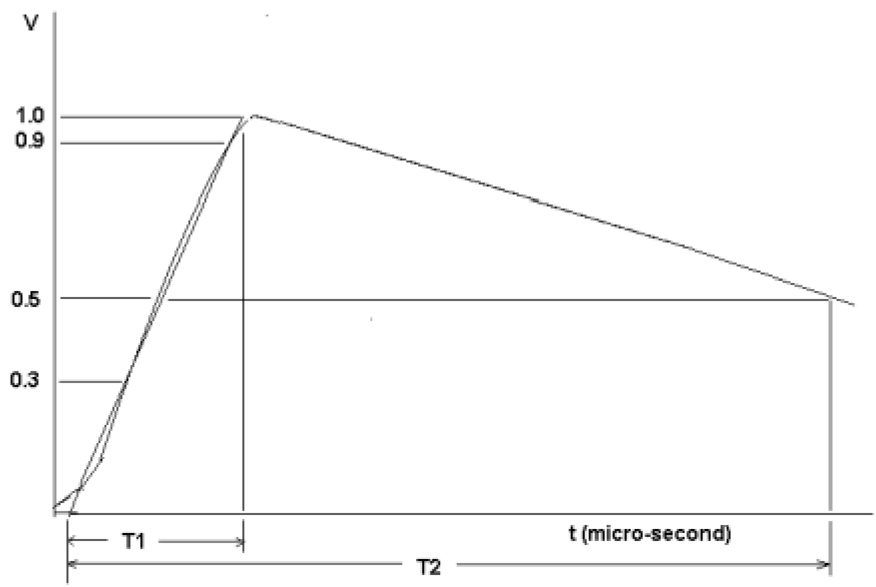

Fig. 2.1 A Standard Impulse Wave [4]

Fig. 2.1 represents a standard impulse wave with T_1 as front or rise time (time taken to reach peak value), T_2 as tail or fall time (time taken to fall 50% of peak value). Indian standard specifications defines 1.2/50 μs duration, 1000kV to be standard impulse, Where front time is 1.2 μs with a tolerance of ±30% and a tail time of 50 μs with a tolerance of ±20% for a 1000kV peak value [1].

2.2 CIRCUITS FOR PRODUCING IMPULSE WAVE

Impulse waves can be produced in the laboratory with a combination of a series R-L-C circuit with over damped conditions or by the combination of two R-C circuits. Various equivalent circuit models that produce impulse waves are shown in Fig. 2.2(a) to 2.2(d). Out of these circuits, the ones shown in Fig. 2.2(b) and (c) are commonly used for experimental purpose. Circuit shown in Fig. 2.2(a) has some limitations as the front time and tail time over a wide range cannot be varied. Commercial generators implement circuits shown in Fig. 2.2(b) to 2.2(d) [1].

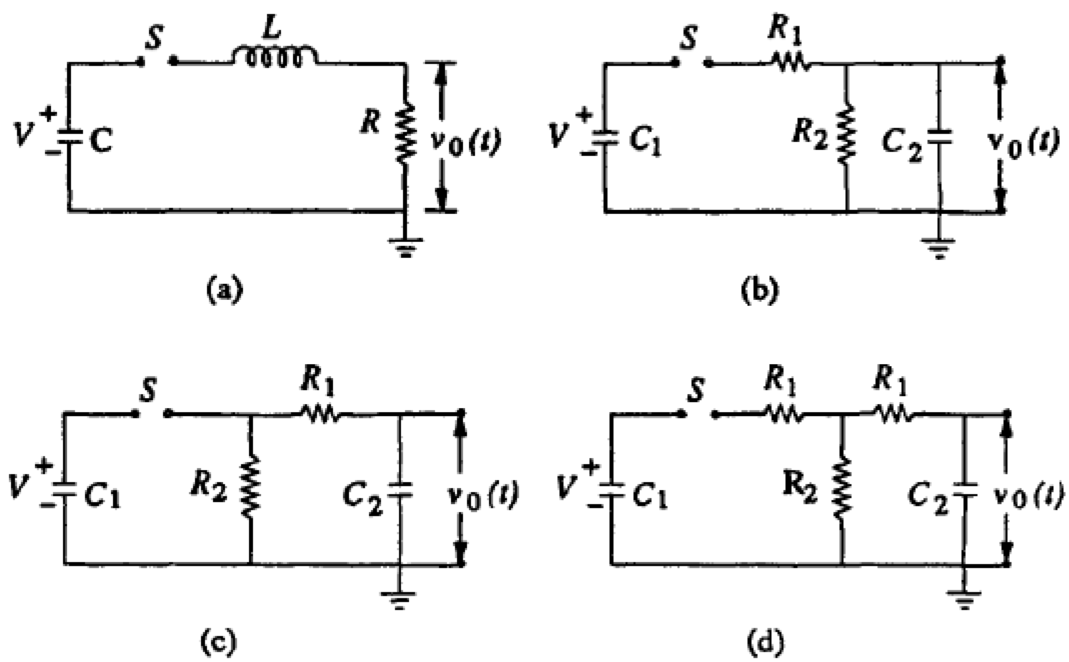

Fig. 2.2 Circuits for Producing Impulse Waves [4]

A capacitor (C_1 or C) which is previously charged to a constant DC voltage is discharged suddenly into a wave shaping network (LR, $R_1R_2C_2$ or other combination) by turning on switch S. The output voltage V_0 (t) gives rise to the desired double exponential impulse wave shape. The impulse generator is designed based on Marx circuit. Fig. 2.2(b) is a basic single stage Marx generator circuit.

2.3 MULTI STAGE IMPULSE GENERATOR MARX CIRCUIT

In the above discussion, the generator capacitance C is to be charged previously to a constant DC voltage level and then discharged into the wave shaping circuits. A single capacitor C may be used for producing pick impulse voltages up to 200 kV. Beyond this pick voltage, a single capacitor and its charging element may be too costly as well as overheating also may cause problem. The size of the whole setup becomes bulky. The size and cost of the impulse generator circuit increases at a rate of the square or cube of the pick impulse voltage rating. Hence, for high impulse wave production, a large number of capacitors are charged simultaneously in parallel and then discharged in series. This arrangement for charging the capacitors in parallel and then discharging them in series was originally developed by Marx. Presently modified Marx circuits are used for the multistage impulse generation.

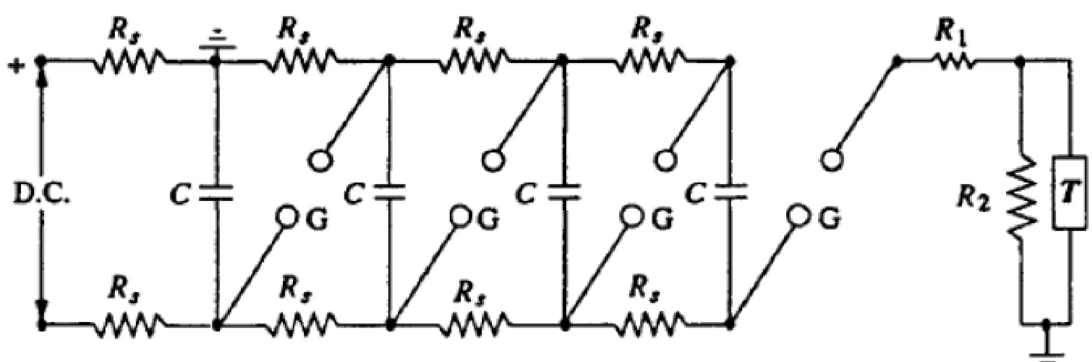

Fig. 2.3 Schematic Diagram of Marx Circuit For Multistage Impulse Generator [4]

In Fig. 2.3, 'C' indicates the charging capacitance of the generator, 'R_s' is charging resistance, 'G' is spark gap, R_1 and R_2 are wave shaping resistor and T is the test object. Wave shaping resistors are further divided into two types which are damping resistor and discharging resistor. Damping resistor control the shape of the impulse voltage wave during rise time whereas discharging resistor control the shape of the impulse voltage wave during tail time. Test object is a capacitor whose value is always less than that of charging capacitor.

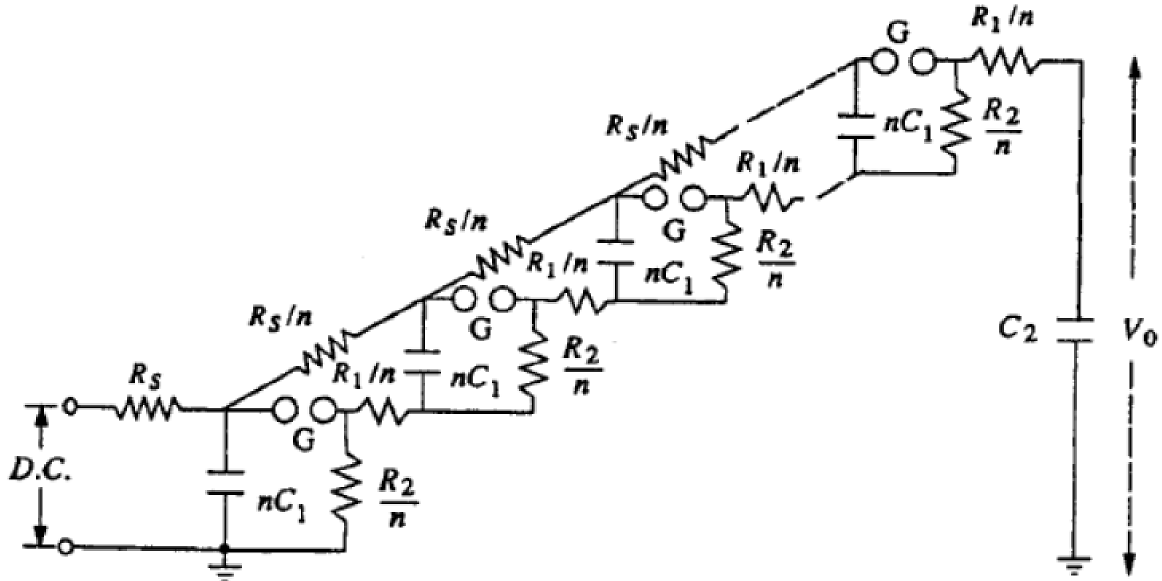

Fig. 2.4 Multistage Impulse Generator Incorporating the Series And Wave Tail Resistances Within Generator [4]

In multistage Marx generator circuit resistive voltage divider are used as shown in Fig. 2.4 in order to minimize the level of voltage to a measureable value across each capacitor. It consists of two impedances which are connected in series and a tapping is introduced in between these resistors in order to connect the sphere gap.

Usually charging resistance R_s is chosen to limit the charging current to about 50 to 100mA, while the generator capacitance C is chosen such that the product $C\times R_s$ is about to 10s to 1 minute. The discharge time constant CR_1/n (for n stages) will be too small (microseconds), compared to the charging time constant $C\times R_s$ which will be few seconds.

Impulse generators are nominally rated by the total voltage (nominal), the number of stages and the gross energy stored. The nominal output voltage is the number of stages multiplied by the charging voltage. The nominal energy stored in the capacitor is given by the equation $E = \frac{1}{2}C_1V^2$. Here, V is nominal maximum voltage (n times charging voltage), C_1 is discharging capacitance. The discharge capacitance, C_1 is given by $C_1 = C/n$. Here, C is capacitance of the generator and n is number of stages of Marx impulse generator circuit. Referring to Fig. 2.4 rise time and tail time of an impulse voltage waveform can be calculated by the given equation. Rise time is 1.25 times of difference between the time taken to reach 90% of peak impulse voltage and time taken to reach 10% of peak impulse voltage. Similarly, tail time is the difference between the time taken to reach 50% of peak impulse voltage during discharging and time taken to reach 10% of peak impulse voltage during charging [5].

The limitation of Marx circuit is that, there may be some error arises because a small amount of current is fed back to the source at each stage through the charging resistor. So, peak impulse voltage appearing across the test object doesn't give the exact theoretical value of the Marx impulse voltage generator [2].

CHAPTER 3

Experimental Setup

3.1 IMPULSE VOLTAGE WAVE SHAPE CONTROL

3.1.1 One Stage Marx generator circuit

Generally, for a given one stage Marx generator circuit (Fig. 2.2b) the limiting values of generator capacitance C_1 and load capacitance C_2 varies as depicted in Table 3.1.

TABLE 3.1

LIMITING VALUES OF C_1/C_2 FOR DIFFERENT STANDARD WAVE

T_1/T_2 (µs)	1.2/5	1.2/50	1.2/200	250/250
Maximum Ratio (C_1/C_2)	5	40	189.19	6.37

For a lighting impulse voltage wave of 1.2/50 µs, the peak impulse voltage appearing across the test object is higher if the ratios of C_1/C_2 is forty or close to this value. Referring to Fig. 2.2b the desired impulse voltage wave shape of time 1.2/50 µs is obtained by controlling the value of $R_1$and R_2. The following approximate analysis is used to calculate the wave front time T_1 and the wave tail time and T_2. The resistance R_2 is very large. Hence, time taken for charging is approximately three times the time constant of the circuit and is given by the formula given below [1].

$$T_1 = 3R_1C_e \qquad (1)$$

Here, C_e is given by the following equation: $C_e = \frac{C_1C_2}{C_1+C_2}$. R_1C_e is the charging time constant in micro-second. For discharging or tail time, the time for 50% discharge is approximately given below.

$$T_2 = 0.7(C_1 + C_2)(R_1 + R_2) \qquad (2)$$

With approximate formulae, the wave front and wave tail can be estimated to within ±20% for the standard impulse waves. Equation (1) can be written as:

$$R_1 = \frac{T_1(C_1+C_2)}{3C_1C_2} \qquad (3)$$

Equation (2) can be written as

$$R_2 = \frac{T_2}{0.7(C_1+C_2)} - R_1 \qquad (4)$$

3.1.2 Multi Stage Marx generator circuit

In multistage Marx generator circuit peak impulse voltage depend on the number of stages included in the circuit. So in multistage Marx generator circuit peak impulse voltage is equal to input voltage applied multiplied by number of stages. For calculating the value of damping resistor, all the charging capacitors which are connected in parallel should be taken into account. Hence, C_1 will be replaced by C_1/n. Where n is the number of stages. The value of charging and discharging capacitor remain same as in the one stage Marx circuit. The value of damping resistor and discharging resistor are given by the following equations [3].

$$R_1 = \frac{T_1((\frac{C_1}{n})+C_2)}{3(\frac{C_1}{n})C_2} \qquad (5)$$

$$R_2 = \frac{T_2}{0.7((\frac{C_1}{n})+C_2)} - R_1 \qquad (6)$$

3.2 PRACTICAL EXPERIMENTAL SETUP FOR IMPULSE VOLTAGE GENERATOR

3.2.1 One Stage Marx Generator Circuit

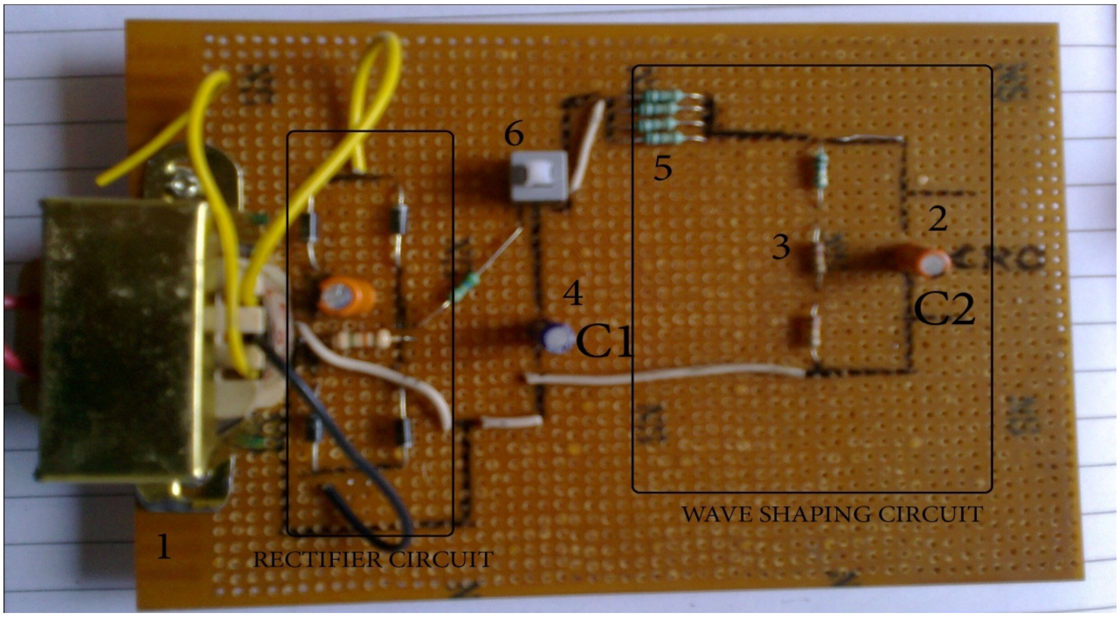

Fig. 3.1 Practical One Stage Marx Generator Circuit

A practical circuit model of one stage Marx Generator circuit is built as shown in Fig. 3.1. The circuit consists of transformer, discharging capacitor C_2 is 1 µF, discharging resistor R_2 is 6.3 Ω, charging capacitor C_1 is 10 µF, damping resistor $R_1$is 0.5 Ω and switch. Combinations of four 1 Ω resistors are connected in parallel and three 2.1 Ω resistor connected in series to obtain the resultant 0.5 Ω (damping resistor) and 6.3 Ω (discharging resistor). Rectifier circuit and wave shaping circuits are indicated by the rectangular portion of the circuit. A 230 V supply is given to the transformer which step downs to 12 V. Then rectifier circuit rectifies 12 V AC (RMS) to 16 V DC which is then supplied to Marx generator circuit. In this circuit sphere gap is replaced by six pin switch which is having two NO contact and two NC contact. Out of these one set of NO and NC contacts are used for simultaneous switching of the circuit.

3.2.2 Two Stage Marx Generator Circuit:

A practical circuit model of two stage Marx Generator circuit is built as shown in Fig. 3.2. The circuits consists of transformer, damping resistor R_1 is 0.5 Ω, switch, discharging capacitor C_1 is 1 µF, discharging resistor R_2 is 11.2 Ω, and two charging capacitor in parallel C_2 is 10 µF. Rectifier circuit and wave shaping circuit are also indicated by the rectangular portion of the circuit.

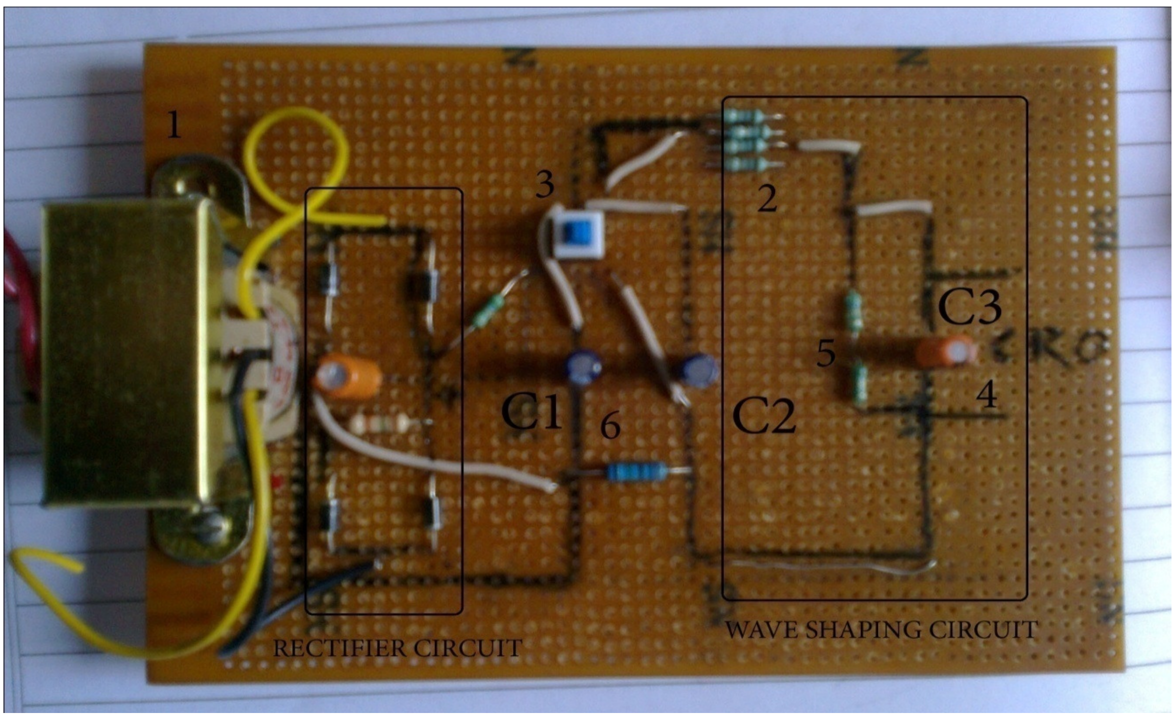

Fig. 3.2 Practical Two Stage Marx Generator Circuit

A 230 V supply is given to the transformer which step downs to 12 V. Then rectifier circuit rectifies 12 V AC (RMS) to 16 V DC which is then supplied to two stages Marx generator circuit. In this circuit sphere gap is replaced by six pin switch which is having two NO contact and two NC contact. Here both sets of NO and NC contacts are used for simultaneous switching of the circuit.

CHAPTER 4

Simulation and Results

4.1 PROCEDURE FOR IMPULSE VOLTAGE GENERATOR CIRCIUT SIMULATION

1. Install the Multisim package of LabVIEW and start the program Multisim 11.0.
2. Go to ‘place’ → ‘component’ → ‘master database’ → ‘all groups’. Then select the required component as shown in the circuit diagram.
3. Then select each component and change maximum rated power, temperature, and value of each component as per the requirement.
4. Connect the oscilloscope across the terminals of discharging capacitor.
5. Now, before simulating the circuits go to ‘simulate’ → ‘interactive simulation setting’. Now set start time to 0 sec, end time to 0.02 sec. Check ‘maximum time step’ (TMAX). Set maximum time step to 2e-008 to control the rate of simulation.
6. Now set switch 1 to ON position and switch 2 to off position. Assign a common keyboard control for both the switches.
7. Now start simulation and alternate the position of switches. When the charging capacitors are charged to its rated value once again alternate the position of switches. Observe the waveform on oscilloscope.
8. Stop the simulation when impulse voltage waveform is obtained.
9. Now go to ‘view’ and open ‘grapher’. Open its properties and auto-arrange the left and bottom axis.
10. Open ‘curser’ → ‘show curser’. Go to set y max and add data label.
11. Note down y coordinate and calculate its 10%, 50% and 90% values.
12. Now click on set y value to obtain the coordinate for 10%, 50% and 90% of peak impulse voltage to Calculate rise time and fall time.

4.2 ONE STAGE MARX GENERATOR CIRCUIT

In one stage Marx impulse voltage generator circuit, all the components are placed in the Multisim project board as shown in Fig. 4.1. The capacitor C_1 is charged to 5V DC. To generate a 1.2/50 μs impulse voltage wave, the required parameters are calculated from equation (1) to equation (6). Front time and tail time of the impulse wave are, T_1 is 1.2 μs and T_2 is 50 μs. Hence, maximum value of C_1/C_2 is 40 (From Table 3.1). Assuming the charging capacitor C_1 to be 10 μF and discharging capacitor C_2 as 1 μF, such that the ratio of C_1/C_2 will be within the given ratio which is 40. Substituting the value of charging capacitor C_1, discharging capacitor C_2, front time T_1 and tail time T_2 in equation (3) and (4) respectively, the value of damping resistor and discharging resistor are found to be R_1 is 0.44Ω ≈ 0.5Ω and R_2 is 6.04 Ω ≈ 6.2Ω. By simulating the circuit with these parameters the result obtained is as follows.

Output peak impulse voltage is found to be 3.44V. Efficiency of the circuit is $\frac{3.44}{5} \times 100$ is equal to 68.8%. Rise time is found to be 1.25 × (40.86 – 40.0944) or 0.957μs. Tail time is found to be (91.2678 - 40.0944) i.e., 51.1734μs. In designing the circuit using LabVIEW Multisim software, the sphere gap for triggering the lightning was replaced by the use of a switch, as shown in Fig 4.1. The circuit was simulated in LabVIEW Multisim using end time value 0.02 second and maximum time step input 2e009 second. Impulse waveform can be seen on oscilloscope output as well as the grapher output. The grapher output waveform can be auto scaled and all the parameters of impulse wave can be calculated from the grapher output tab. Rate of simulation can be changed by changing the value of maximum time step input. The simulated circuit and its waveform are shown in Fig. 4.1 and Fig. 4.2.

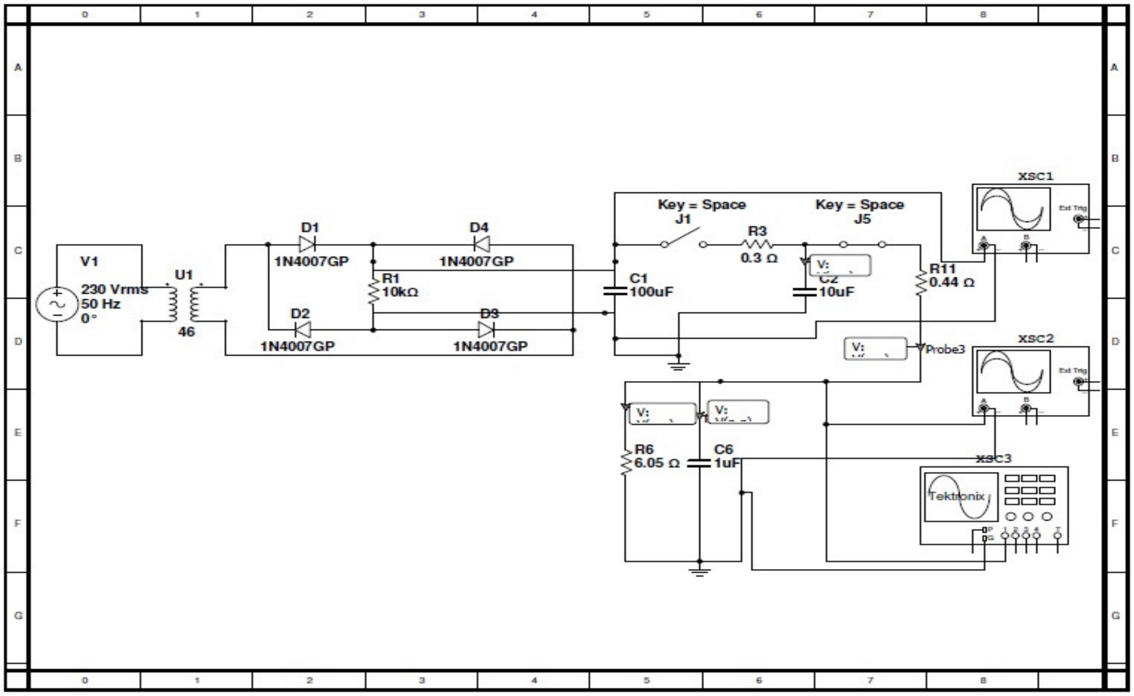

Fig. 4.1 Simulation Circuit for One Stage Marx Generator

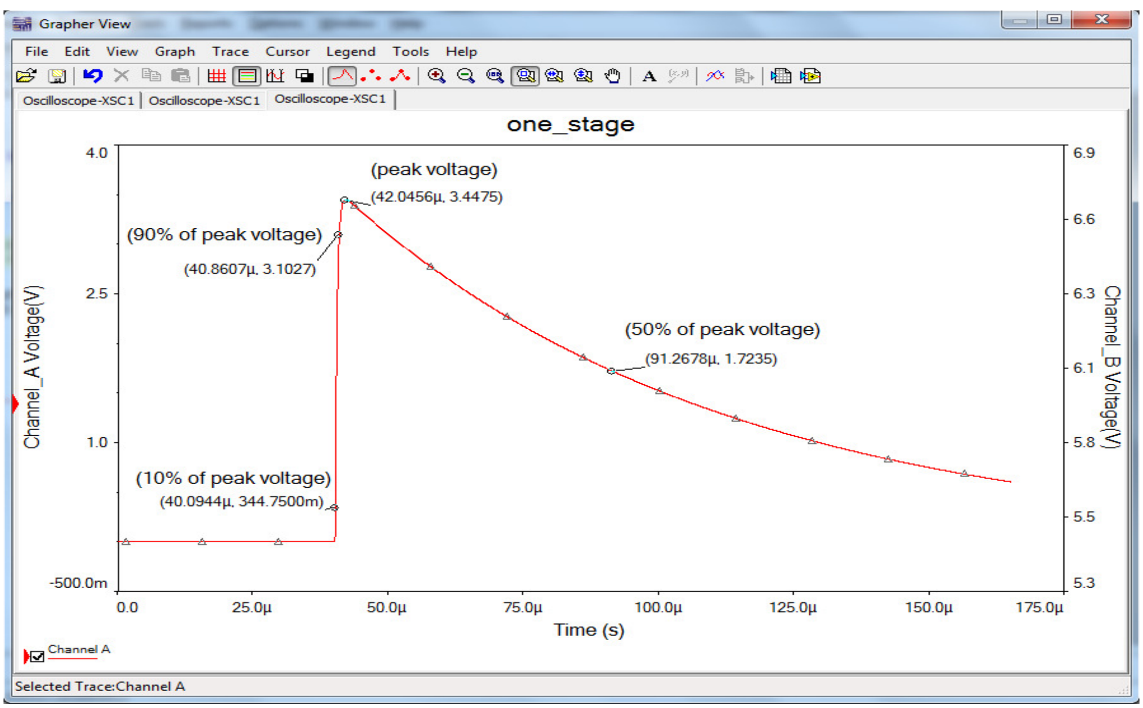

Fig. 4.2 Grapher Output Showing a One Stage Marx Circuit

4.2 TWO STAGE MARX GENERATOR CIRCUIT

Referring to Fig. 4.3 the charging capacitor C_1 and C_2 are charged to 5V DC. So to generate a 1.2/50 µs impulse wave, following parameters are calculated from equation (1) to equation (6). Front time and tail time of the impulse wave are, T_1 is 1.2 µs and T_2 is 50 µs. Hence, maximum value of C_1/C_2 is 40 (From Table 3.1). The two charging capacitors C_1 of value 10 µF and discharging capacitor C_2 of 1 µF is taken such that the ratio of C_1/C_2 will be within the limit, which is 40. Substituting the value of charging capacitors C_1, discharging capacitor C_2, front time T_1 and tail time T_2 in equation (3) and (4) respectively, the value of damping resistor and discharging resistor are found to be R_1 which is 0.48 $\Omega \approx 0.5\Omega$ and R_2 is $11.42\Omega \approx 11.2\Omega$. By simulating the circuit with these parameters the result obtained is as follows.

Output peak impulse voltage was 4.3102 V. Efficiency of the circuit is given by $\frac{4.3}{5*2} \times 100$ or 43%. Rise time is found to be 1.25 × (209.064-208.2491) or 1.01µs. Tail time is 256.5971-208.2491 i.e., 48.348 µs. In designing the circuit using LabVIEW Multisim software, the sphere gap for triggering the lightning was replaced by the use of a switch, as shown in Fig 4.3. The circuit was simulated in LabVIEW Multisim using end time value 0.02 second and maximum time step input 2e008.5 second. Impulse waveform can be seen on oscilloscope output as well as the grapher output. The grapher output waveform can be auto scaled and all the parameters of impulse wave can be calculated from the grapher output tab. Rate of simulation can be changed by changing the value of maximum time step input. The grapher output waveform of the impulse voltage wave is shown in Fig. 4.4.

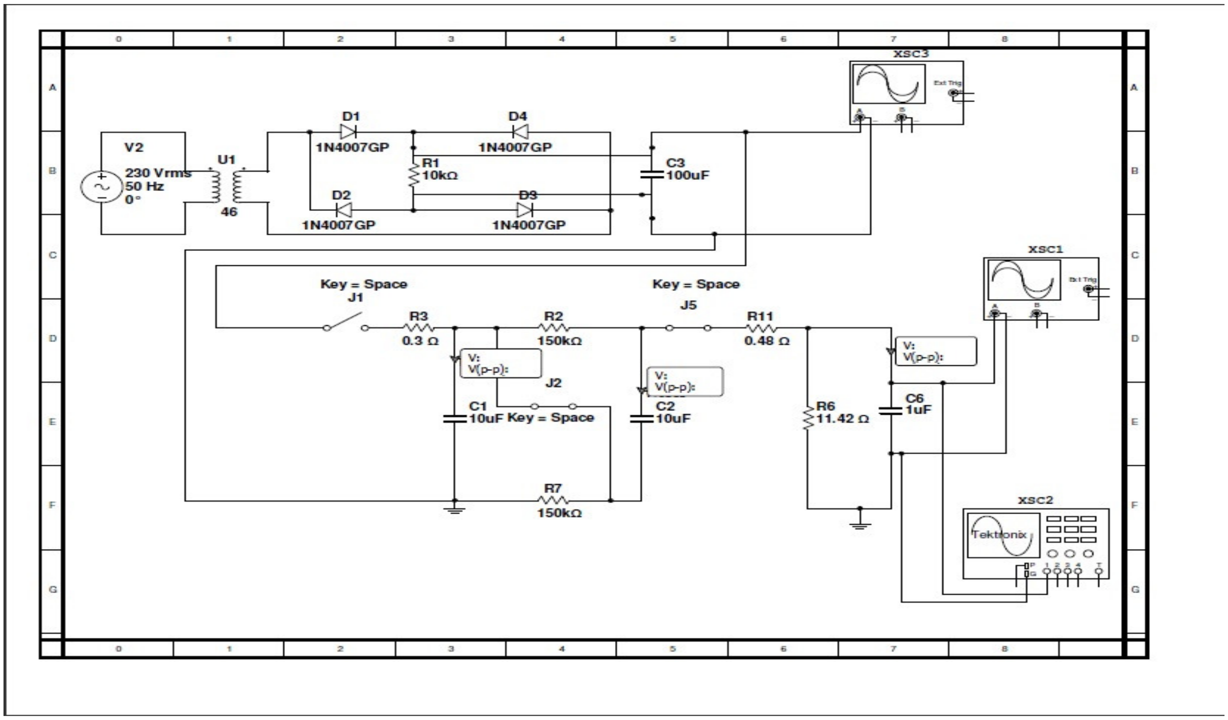

Fig. 4.3 Simulation Circuit for Two Stage Marx Generator

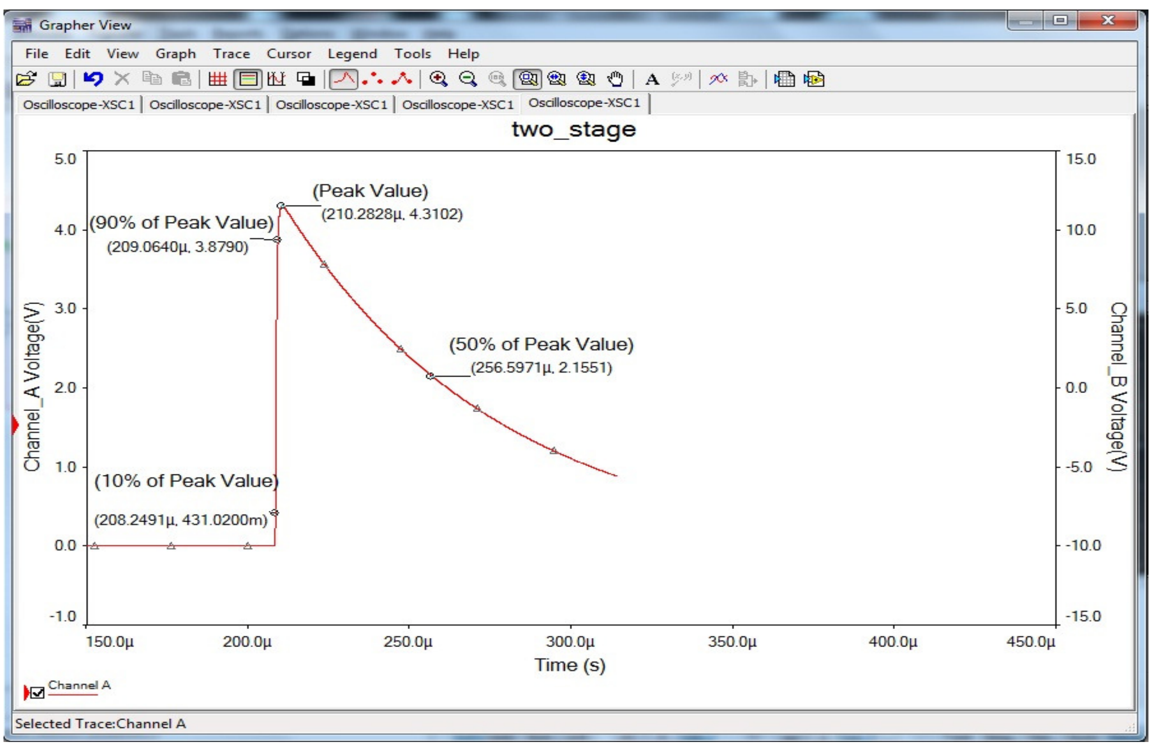

Fig. 4.4 Grapher Output Showing Two Stage Marx Circuit

4.4 THREE STAGE MARX GENERATOR CIRCUIT:

According to Fig. 4.5 the charging capacitor C_1 and C_2 are charged to 15V DC. So to generate a 1.2/50 µs impulse wave, following parameters are calculated from equation (1) to equation (6). Front time and tail time of the impulse wave are, T_1 is 1.2 µs and T_2 is 50 µs. Hence maximum value of C_1/C_2 is 40 (From Table 3.1). The three charging capacitors C_1 of magnitude 10 µF each and discharging capacitor C_2 of 1 µF is taken such that the ratio of C_1/C_2 will be within the limit that is 40. Substituting the value of charging capacitor C_1, discharging capacitor C_2, front time T_1 and tail time T_2 in equation (3) and (4) respectively, the value of damping resistor and discharging resistor are found to be R_1 which is 1.106 Ω ≈ 1 Ω and R_2 is 33.965 Ω ≈ 34Ω. By simulating the circuit with these parameters the result obtained is as follows.

Output peak impulse voltage was 34.4451 V. Efficiency of the circuit is given by $\frac{34.4451}{15.6*3} \times 100$, or 73.6%. Rise time is found to be 1.25 × (8.0166-7.2923) i.e., 0.973µs. Tail time is 256.5971-208.2491 or 51.014µs. In designing the circuit using LabVIEW Multisim software, the sphere gap for triggering the lightning was replaced by the use of a switch, as shown in Fig 4.5. The circuit was simulated in LabVIEW Multisim using end time value 0.02 second and maximum time step input $2\times 10^{7.5}$ second. Impulse waveform can be seen on oscilloscope output as well as the grapher output. The grapher output waveform can be auto scaled and all the parameters of impulse wave can be calculated from the grapher output tab. Rate of simulation can be changed by changing the value of maximum time step input. The grapher output waveform is shown in Fig. 4.6.

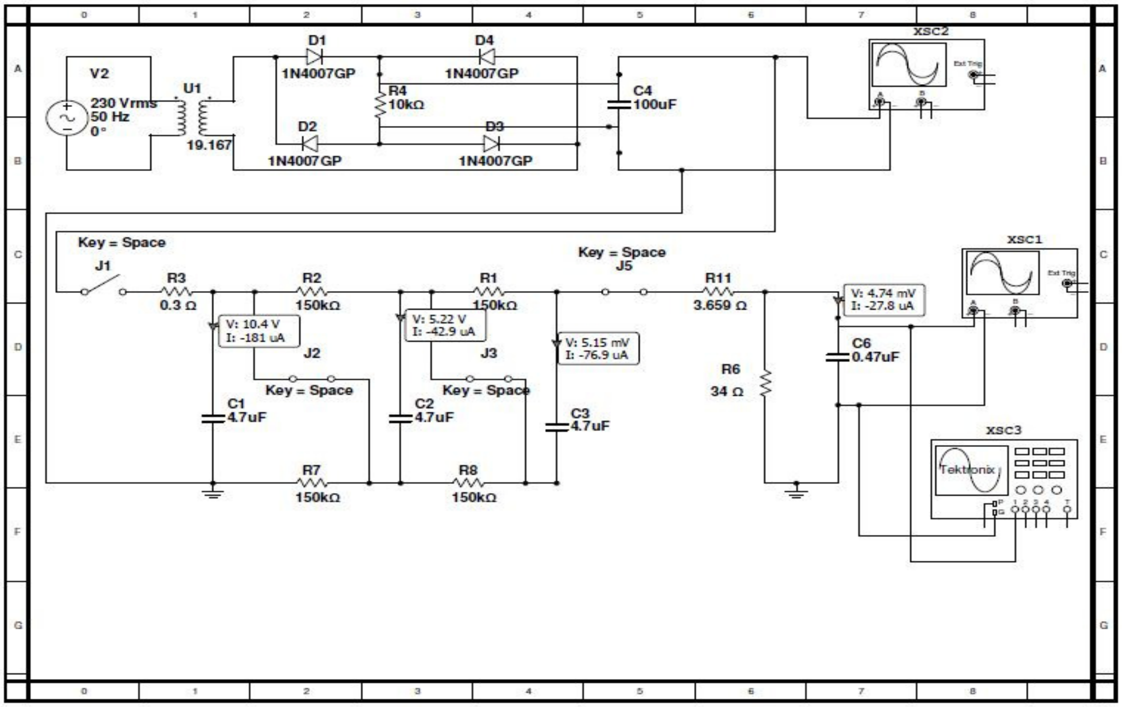

Fig. 4.5 Simulation Circuit for Three Stage Marx Generator

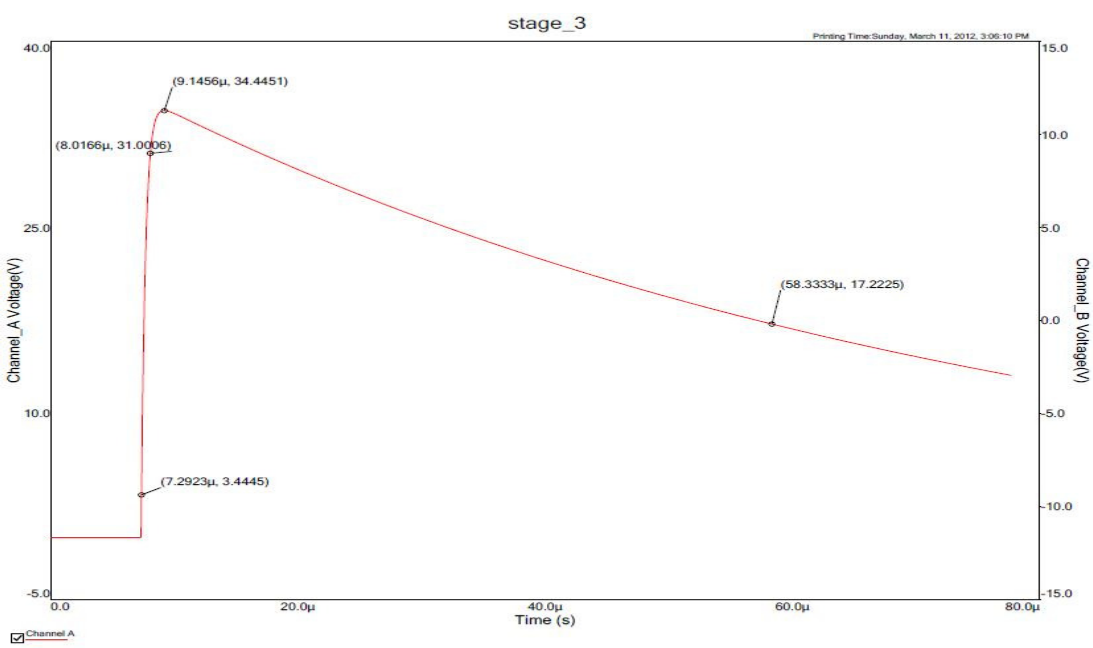

Fig. 4.6 Grapher Output Showing a Three Stage Marx Circuit

4.5 FOUR STAGE MARX GENERATOR CIRCUIT

The charging capacitor C_1 and C_2 are charged to 15V DC. So, to generate a 1.2/50 µs impulse wave, following parameters are calculated from equation (1) to equation (6). Front time and tail time of the impulse wave are, T_1 is 1.2 µs and T_2 is 50 µs. Hence, maximum value of C_1/C_2 is 40 (From Table 3.1). Let four charging capacitors C_1 which are 4.7µF and discharging capacitor C_2 is 0.47 µF was taken, such that the ratio of C_1/C_2 be within the limit that is 40. Substituting the value of charging capacitor C_1, discharging capacitor C_2, front time T_1 and tail time T_2 in equation (3) and (4) respectively, the value of damping resistor and discharging resistor are found to be R_1 which is 1.19Ω ≈ 1.2Ω and R_2 is 42.23 Ω ≈ 42 Ω. By simulating the circuit with these parameters the result obtained is as follows.

Output peak impulse voltage was 42.6518 V. Efficiency of the circuit is given by $\frac{42.6518}{15.6*4}\times 100$ or 68.35 %. Rise time is found to be 1.25 × (7.5204-6.7164) or 1.005µs. Tail time is 51.0092 µs. In designing the circuit using LabVIEW Multisim software, the sphere gap for triggering the lightning was replaced by the use of a switch, as shown in Fig 4.7. The circuit was simulated in LabVIEW Multisim using end time value 0.02 second and maximum time step input 2×10^{6} second. Here faster rate of simulation is preferred because in order to charge all the capacitors in parallel. Impulse waveform can be seen on oscilloscope output as well as the grapher output. The grapher output waveform can be auto scaled and all the parameters of impulse wave can be calculated from the grapher output tab. Rate of simulation can be changed by changing the value of maximum time step input. The impulse wave generated is shown in Fig. 4.8.

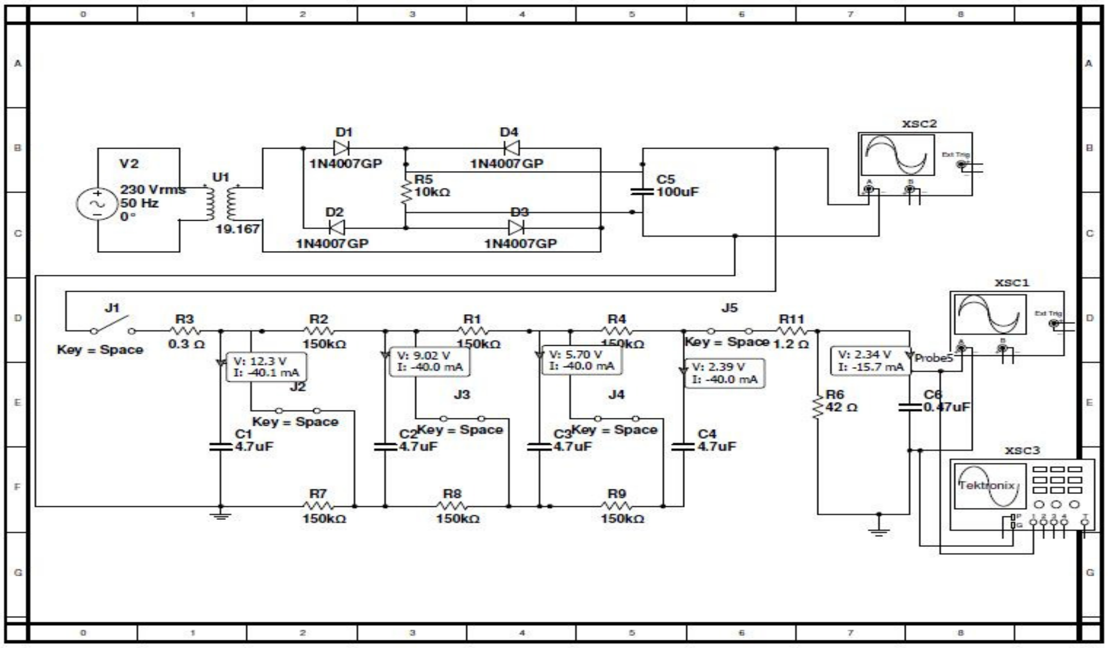

Fig. 4.7 Simulation Circuit for Four Stage Marx Generator

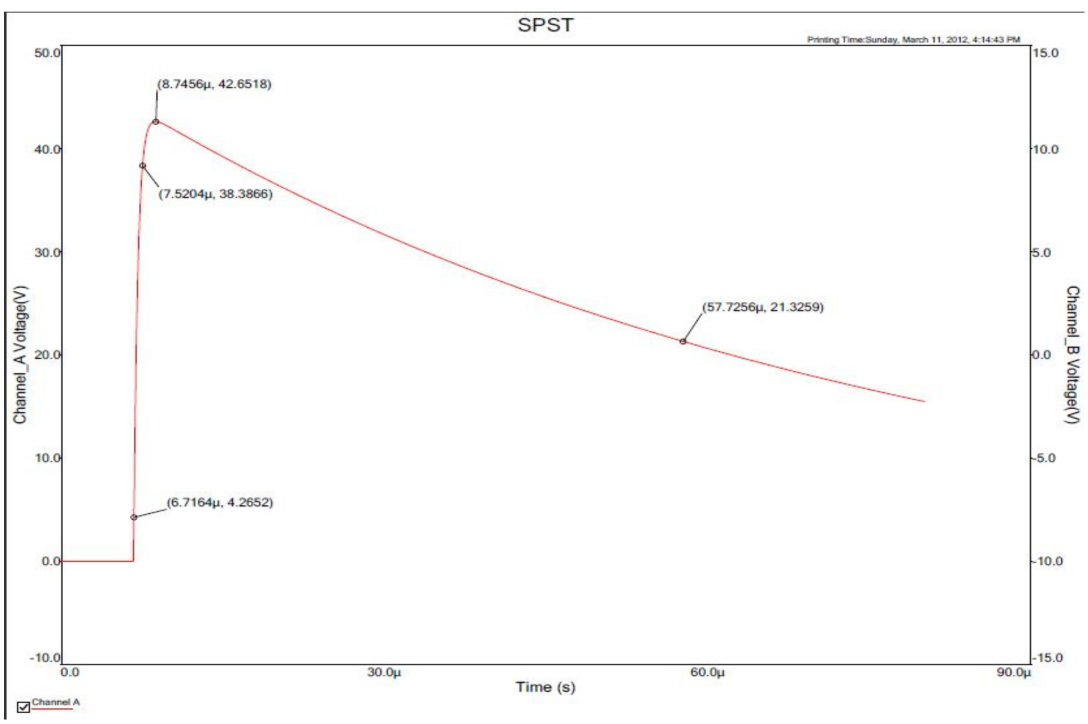

Fig. 4.8 Grapher Output Showing a Four Stage Marx Circuit

4.6 PRACTICAL CIRCUIT ANALYSIS

4.6.1 One stage Marx circuit

Referring to Fig. 3.1 the charging capacitor (C_1) is charged to 5V using AC adaptor. Then it is discharged through the wave shaping circuit and discharging capacitor (C_2) by turning off the switch 'S'. The impulse voltage waveform is observed across the capacitor C_2 through digital oscilloscope is as shown in Fig. 4.9. Peak impulse voltage of the single stage Marx generator circuit was found to be 2.44 V. Rise time and tail time of this impulse voltage wave are 2.2 µs and 76 µs.

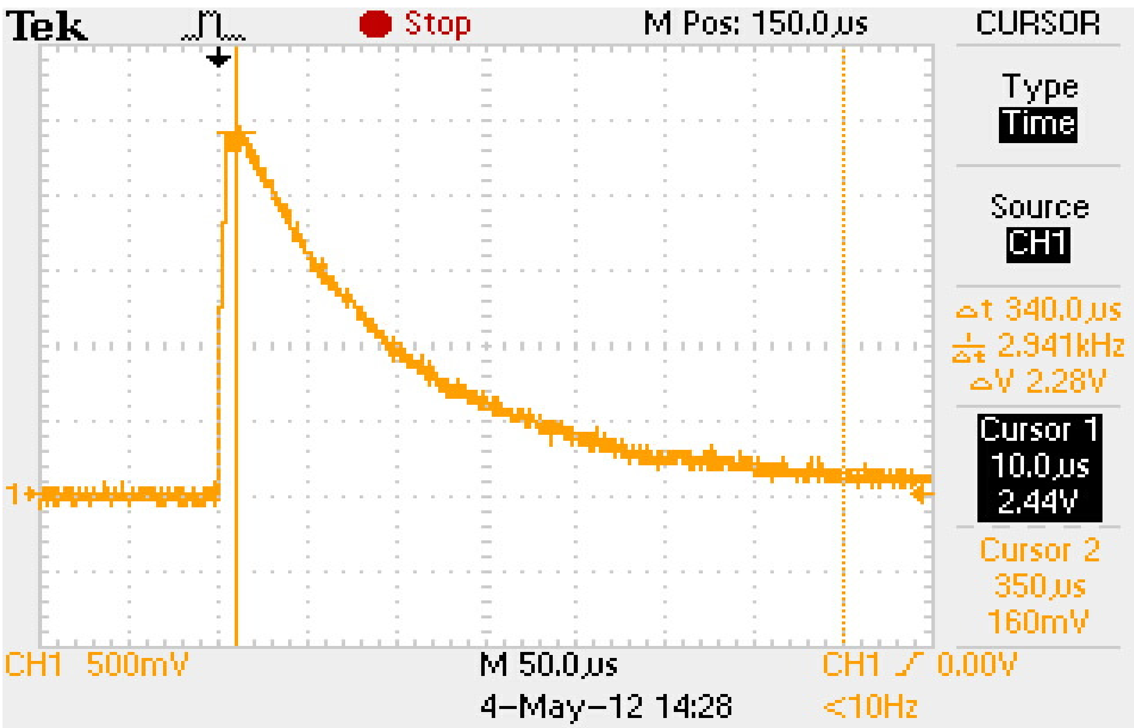

Fig. 4.9 Digital Oscilloscope Output Of Practical One Stage Marx Generator

4.6.2 Two stage Marx circuit

Referring to Fig. 3.2, the charging capacitors (C_1& C_2) are charged to 5V using AC adaptor. Then the switch 'S' is turned off to discharge both the capacitors (C_1& C_2) in series through the wave shaping circuit and discharging capacitor (C_3). The impulse voltage waveform across the capacitor C_3 is observed using digital oscilloscope as shown in Fig. 4.10. Then the value of front time, tail time and peak impulse voltage are calculated by changing the position of the curser in the digital oscilloscope to 10%, 90% and 50% of the peak impulse voltage level. Thus the peak impulse voltage is 3.2 V. Rise time and tail time of the impulse voltage waveform are 2.1 µs and 80 µs respectively.

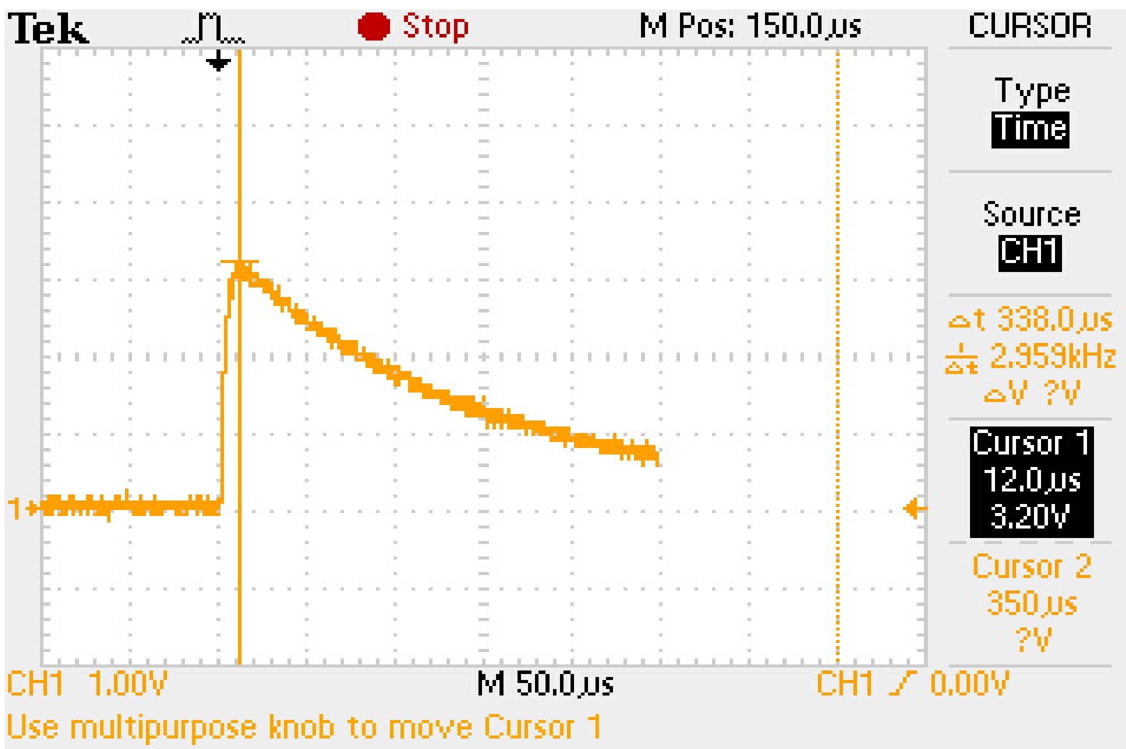

Fig. 4.10 Digital Oscilloscope Output of Practical Two Stage Marx Generator Circuit.

TABLE 4.1
DIFFERENT PARAMETERS OBSERVED IN IMPULSE VOLTAGE GENERATION FOR BOTH SIMULATION AND PRACTICAL CIRCUIT

Stage	Rise Time (μsec)	Tail Time (μsec)	Efficiency	% Error in Rise time	% Error in Tail time
Simulated data					
1	0.957	51.1734	68.8%	20.2	2.346
2	1.01	48.348	43%	15.83	3.304
3	0.973	51.014	73.6%	18.91	2.028
4	1.005	51.0092	68.35%	16.25	2.018
Experimental data					
1	1.8	76	48.8%	50	52
2	1.7	80	32%	41	60

4.7 Comparison between practical Marx circuit model and simulated Marx circuit model

Finally the waveforms obtained from the one stage Marx circuit of practical impulse voltage generator circuit model is compared with that of the simulated circuit model through LabVIEW Multisim which is depicted in Table 4.1. The data is collected from both the cases and the impulse voltage waveform plotted which is shown in Fig. 4.11. Curve 1 represents impulse voltage waveform of practical circuit model obtained from digital oscilloscope. Curve 2 indicates impulse voltage waveform of simulated circuit.

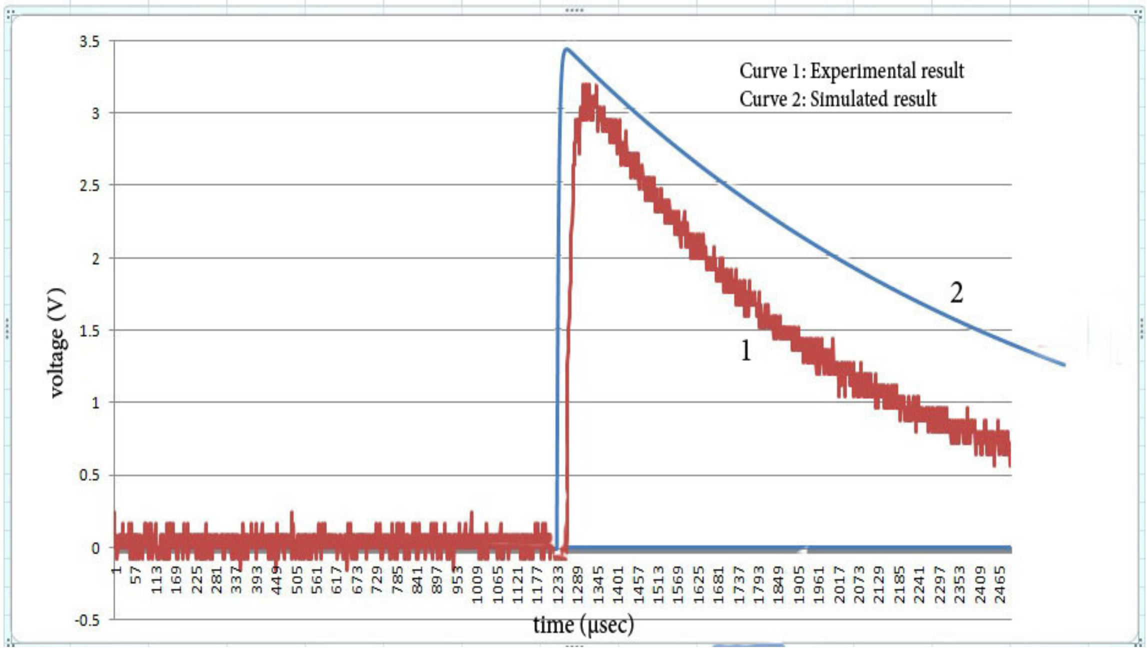

Fig. 4.11 Comparison Between Practical Marx Circuit Model And Simulated Circuit Model

In Fig. 4.11, peak impulse voltage of the experimental impulse voltage wave is 3.2 V, where as peak impulse voltage of the simulated impulse voltage wave is 3.48 V. This difference in the simulated result and experimental result is because of significant voltage drop across the charging resistor. The discrepancy in the rise time and fall time of the two curve is due to some tolerance allowed in the damping resistor and discharging resistor.

CHAPTER 5

Conclusion and Future Work

The generation of high impulse voltage is implemented in reduced scale and also in the simulation with the LabVIEW Multisim software environment. It is found that the overall simulated result and the observed impulse voltage result from the experimental setup is close to standard impulse generator 1.2 / 50 μs wave shape for all four stages of Marx generator. The wave shapes are controlled by changing stage front resistor and tail resistor. Rise time is controlled by changing stage front resistor and tail time is controlled by changing tail resistor. Peak value of each impulse wave is varied by changing initial charging of stray capacitance. The tolerances that is allowed in the front and tail times are respectively ± 30% and ±20 %. Rise time and tail time of impulse voltage wave obtained from simulated data are within tolerance limit, but variation in rise time and fall time of practical Marx circuit is due to following reasons. For obtaining maximum peak voltage the ratio of capacitance of charging capacitor and discharging capacitor is taken 10. The error in rise time and fall time is because of some tolerance label in damping resistor and discharging resistor. It is also observed that a small change in the resistance value can cause significant change in rise time and fall time of the impulse voltage. In the practical impulse generation circuit model sphere gap is replaced by six pin switch so that all the capacitors are discharged at one instant.

In this work, generation of high impulse voltage, data acquisition (stand alone system) of impulse wave has been presented. This work can be further extended by transferring acquired data to other PC through data communication and networking involving Ethernet as well as interfacing the circuit with pc for controlling the circuit through pc control.

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